



DEPARTMENT OF HEALTH & HUMAN SERVICES

National Institutes of Health  
National Institute of Neurological  
Disorders and Stroke

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April 10, 2000.

The Honorable Edward J. Markey  
United States House of Representatives  
Washington, DC 20515

Dear Representative Markey:

Your letter to Dr. Ruth Kirschstein, Acting Director, NIH, asking for assistance in understanding the state of scientific knowledge concerning injuries caused by amusement park rides has been referred to me for reply. The National Institute of Neurological Disorders and Stroke (NINDS) is the lead NIH institute responsible for research on the brain and nervous system, including traumatic brain injury.

Specifically, you asked for information in the scientific literature about the risk of subdural hematoma, internal cranial bleeding, stroke, and other similar outcomes from high-speed, high g-force roller coasters or under circumstances of comparable force. You also requested information about research supported by NIH related to brain injuries from this or comparable trauma. Included with your letter was a copy of a recent article in *Neurology* 2000; 54:264, which contained three recent case reports of patients who developed subdural hematomas after riding roller coasters.

In Fiscal Year 1999, NINDS funded \$35.9 million in research related to traumatic brain injury (TBI), and we estimate that FY 2000 funding related to TBI research will be \$39.1 million. NINDS-supported TBI research focuses on understanding the mechanisms and consequences of injury to the brain. Major emphasis is placed on the prevention of secondary damage, preservation of neurons and neural circuits, regeneration and plasticity. NINDS grantees are exploring a variety of interventions to limit damage resulting from trauma and to promote repair of the damaged nervous system, as well as conducting research on ways to promote recovery of cognitive and language function following brain injury.

NINDS is not currently supporting any research looking specifically at brain injuries that might be associated with roller coasters, nor studying the impact of specific g-force exposures on the brain. However, we do support a significant amount of research on diffuse axonal injury (DAI), which is a major pathological feature of traumatic brain injury. Even mild DAI can result in chronic cognitive and behavioral changes, but may be undetectable using standard imaging techniques. This type of damage can occur in non-impact, rotational acceleration brain injury, which could result if the unrestrained head was turned perpendicular to the direction of the acceleration/deceleration at the onset of the force. The Institute also supports research to develop animal and computational models of traumatic brain injury, and to conduct biomechanical analyses of TBI models. NINDS-supported researchers at the University of Pennsylvania have developed a pneumatic actuator to conduct

rotational acceleration injury studies using a pig model. I have included abstracts for a few projects on these topics that may be of particular interest to you.

My staff conducted a literature search, and also asked the National Library of Medicine (NLM) to do so. The initial NLM search focused on roller coaster effects, and retrieved 23 citations; a copy of the full-text journal article or letter is included, if it was available in English or in an English translation. Two subsequent searches focused on broader categories of whiplash and hematoma and whiplash and other brain injuries; the citations and, in some cases, the abstracts are provided for these searches. We can get the full-text of these articles also, if you decide they would be useful. I have included an article and an editorial from the medical literature that address brain damage after whiplash injury and will acquaint you with some of the issues involved with this type of injury.

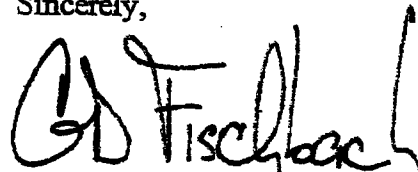
I have also enclosed two in press articles on axonal damage in traumatic brain injury co-authored by Douglas H. Smith, M.D., of the University of Pennsylvania. The work reported by Dr. Smith was supported by NIH grants. These articles have been accepted for publication in *The Neuroscientist* and in the *Journal of Neurosurgery*, and Dr. Smith has generously permitted us to share them with you. However, since these two articles have not yet been published, I ask that you consult Dr. Smith before distributing them further. Dr. Smith can be reached at 215-898-0881.

A copy of Chapter 4, "Sustained Linear Acceleration," and Chapter 5, "Rotary Acceleration," from the Bioastronautics Data Book, 2<sup>nd</sup> edition, published by the National Aeronautics and Space Administration (NASA) are also enclosed, at the suggestion of Dr. Malcolm Cohen of the Ames Research Center. Dr. Cohen has particular expertise on sustained linear acceleration, and would be pleased to discuss this topic and his research directly with you; Dr. Cohen can be reached at 650-604-6441.

Finally, as general background information, I have included information on the epidemiology of traumatic brain injury in the United States which has been collected by the National Center for Injury Prevention and Control, Centers for Disease Control and Prevention (CDC). The CDC's ongoing surveillance activities in TBI may be of interest to you and serve as another source of data on this important topic.

I commend your efforts to determine whether particular types of unregulated activities pose a public health risk, particularly with regard to brain injury. If we can be of further assistance, please do not hesitate to contact me, or Ms. Lorraine Fitzsimmons, in the NINDS Science Policy and Analysis Branch, at 301-496-9271.

Sincerely,

A handwritten signature in black ink, appearing to read "G.D. Fischbach". The signature is stylized with a large, looped "G" and a long, sweeping horizontal stroke at the end.

Gerald D. Fischbach, M.D.  
Director

Enclosures

Roller Coaster Effects  
MEDLINE 1966-March 2000  
23 Citations

Biousse V, Chabriat H, Amarenco P, Bousser MG. Roller-coaster-induced vertebral artery dissection [letter]. *Lancet* 1995 Sep 16; 346(8977):767.  
SUBJECT HEADINGS: Adult/Case Report/Cerebellar Diseases/etiology/Cerebral Infarction/etiology/Female/Human/\*Recreation/Vertebral Artery/\*injuries

Bo-Abbas Y, Bolton CF. Roller-coaster headache [letter]. *N Engl J Med* 1995 Jun 8; 332(23):1585.  
SUBJECT HEADINGS: Case Report/Chronic Disease/Headache/\*etiology/Hematoma, Subdural/complications/\*etiology/Human/Male/Middle Age/\*Recreation

Fernandes CM, Daya MR. A roller coaster headache: case report. *J Trauma* 1994 Dec; 37(6):1007-10.  
ABSTRACT: There are few reports of adverse outcomes associated with roller coaster rides. We present the case of a 26-year-old man who complained of a gradually worsening headache following a roller coaster ride. A computed tomographic scan of the head demonstrated bilateral chronic subdural hematomas. The clinical course and probable mechanism of injury are reviewed.  
SUBJECT HEADINGS: Adult/Case Report/Headache/\*etiology/Hematoma, Subdural/complications/\*etiology/radiography/Human/Male/\*Recreation/Tomography, X-Ray Computed

Fukutake T, Mine S, Yamakami I, Yamaura A, Hattori T. Roller coaster headache and subdural hematoma. *Neurology* 2000 Jan 11;54(1):264.  
SUBJECT HEADINGS: Adult/Case Report/Female/Headache/\*etiology/Hematoma, Subdural/diagnosis/\*etiology/surgery/Human/Magnetic Resonance Imaging/\*Recreation

Glad WR. [Injuries to visitors in an amusement park. Results of 5 years' registration of injuries in the Kristinsand Amusement Park]. *Tidsskr Nor Lægeforen* 1988 Jun 30;108(19-21):1459-63. (Nor).

SUBJECT HEADINGS: Adolescence/Age Factors/Child/Child, Preschool/English Abstract/Female/Human/Infant/\*Leisure Activities/Male/Norway/\*Play and Playthings/Sex Factors/Wounds and Injuries/\*epidemiology/prevention & control

Holtzman DK, Paul RL. Roller coasters: let the rider beware. *Pediatr Emerg Care* 1997 Jun; 13(3):218-20.

ABSTRACT: PURPOSE: To describe a pediatric patient with a severe abdominal injury following a roller coaster crash, and to review the relevant literature of lap belt injuries and roller coaster safety regulations. METHODS: Case report. RESULTS: A seven-year-old girl sitting in the front seat of a two-person roller coaster car was injured when it crashed into the stopped car in front. The patient's injuries, including a partial hepatic amputation, were due to the combined forces of both passengers applied against her lap belt. CONCLUSIONS: Roller coaster restraint systems do not have the same federal or state oversights as motor vehicles and can result in life-threatening injuries.

SUBJECT HEADINGS: \*Accidents/Case Report/Child/Female/Human/Liver/\*injuries/Play and Playthings/\*injuries/Seat Belts/\*adverse effects

Jones CH. CAPD catheter malposition during a roller coaster ride [letter]. *Perit Dial Int* 1996 May-Jun;16(3):329-30.

SUBJECT HEADINGS: Adult/Case Report/\*Catheters, Indwelling/Human/Male/Peritoneal Dialysis, Continuous Ambulatory/\*adverse effects/instrumentation

Kettaneh A, Biousse V, Bousser MG. [In Process Citation]. *Presse Med* 2000 Feb 5;29(4):175-80 (Fre).

ABSTRACT: OBJECTIVE: To describe neurological complications occurring after roller-

coaster rides. **PATIENTS AND METHODS:** We report 6 cases of complications occurring after roller-coaster rides and analyze published data. **RESULTS:** Complications seen our patients included 5 cervicoencephalic arterial dissections, one with brainstem dysfunction due to extending syringobulbia. Reported data include one cervicoencephalic arterial dissection, one case of carotid artery occlusion, 3 cases of subdural hematoma, one with subarachnoid hemorrhage, one with cerebrospinal fluid leak, and one with Brown-Sequard syndrome secondary to an enterogenous cyst of the spinal cord. In all patients, pain was the first symptom experienced. In 71.4% of cases, it occurred immediately after the trauma. Marfanis syndrome may be the only risk factor identifiable prior to exposure. The mechanisms of most complications are poorly understood but are likely to involve sudden head and neck flexion-extension movements. **CONCLUSION:** Neurological complications occurring after roller-coaster rides are highly uncommon, but may leave invalidating sequelae or be fatal. Clinicians should be aware of these complications so these patients can be given proper care early, particularly at the stage when pain is the only sign. Early management could help limit the consequences of these complications.

Kettaneh A, Biousse V, Bousson V, Bousser MG. Roller-coaster syringomyelia. *Neurology* 1998 Aug;51(2):637-8.  
**SUBJECT HEADINGS:** Adult/Brain Stem/pathology/Case Report/Human/Magnetic Resonance Imaging/Male/Movement/\*physiology/\*Recreation/Syringomyelia/diagnosis/\*physiopathology

Kiesouw L. Is there a down side to the thrill of rollercoaster rides? [news]. *S Afr Med J* 1999 Aug;89(8):824-5.  
**SUBJECT HEADINGS:** Human/Posture/\*Recreation/\*Safety/Whiplash Injuries/\*etiology

Larsen K, Espersen G. [Injuries in a summer amusement park treated at the first-aid station and the casualty department]. *Ugeskr Laeger* 1987 Mar 23;149(13):877-9 (Dan).

**SUBJECT HEADINGS:** Accidents/Adolescence/Adult/Child/Child, Preschool/Denmark/Emergencies/English Abstract/Female/Human/Male/\*Play and Playthings/Wounds and Injuries/\*epidemiology/etiology/therapy

Novotny I, Shul'ts I. [Acute cerebrovascular diseases in pilots]. *Kosm Biol Aviakosm Med* 1988 May-Jun;22(3):82-4 (Rus).  
**ABSTRACT:** The problem of acute cerebrovascular diseases in pilots is discussed. During the last 10 years 15 pilots were examined. In 8 of them the disorders developed when they were career pilots and 7 of them were grounded before due to different reasons. A detailed analysis is given to the case of massive hemorrhage into the subarachnoidal space which developed in a test-pilot when he was suddenly subjected to medium-intensity acceleration of opposite sign.  
**SUBJECT HEADINGS:** Acceleration/\*adverse effects/Acute Disease/Adult/\*Aerospace Medicine/Case Report/Cerebral Hemorrhage/\*etiology/English Abstract/Human/Male/Middle Age/Occupational Diseases/\*etiology/Risk Factors

Oganesian SS. [Diagnosis and surgery of chronic subdural hematomas]. *Vopr Neurokhir* 1970 Sep-Oct;34(5):22-4 (Rus).  
**SUBJECT HEADINGS:** Adult/Aged/Child/Chronic Disease/Craniocerebral Trauma/English Abstract/Female/Hematoma, Subdural/\*diagnosis/etiology/\*surgery/Human/Male/Middle Age/Trephining

Olsen PA. Injuries in children associated with trampolinelike air cushions. *J Pediatr Orthop* 1988 Jul-Aug;8(4):458-60.  
**ABSTRACT:** During a 7-month period, we registered 112 children who had been injured in an amusement park. Despite the large number of other playground apparatuses, 78 injuries were associated with jumping on three giant air cushion trampolinelike apparatuses. Moreover, the air cushions caused a significantly larger number of severe and moderate injuries than did other apparatuses (p less than 0.01). Thirty-one

percent of the injuries were fractures or growth plate lesions. Seventy percent of the children explained that they had either been pushed or had lost their balance because of the constantly changing rhythm of the canvas. We therefore warn against this trampolinelike apparatus.

**SUBJECT HEADINGS:**

Adolescence/Child/Child,  
Preschool/Contusions/\*etiology/Dislocations/\*etiology/\*Evaluation Studies/Female/  
Fractures/\*etiology/Growth  
Plate/injuries/Human/Infant/Male/\*Play and  
Playthings/\*Product Surveillance,  
Postmarketing/Prospective Studies

Pringle SD, Macfarlane PW, Cobbe SM.  
Response of heart rate to a roller coaster ride.  
BMJ 1989 Dec 23-30;299(6715):1575.

**SUBJECT HEADINGS:**

Adult/Electrocardiography/Female/\*Heart  
Rate/Human/Male/\*Recreation/Support, Non-  
U.S. Gov't

Scano A. [Changes in the accelerative field in some common amusement-park devices and vehicles]. Riv Med Aeronaut Spaz 1970 Jan-Mar;33(1):133-9. (Ita).

**SUBJECT HEADINGS:**

\*Acceleration/\*Cardiovascular  
Physiology/Cardiovascular  
System/\*physiology/English  
Abstract/Human/Nervous  
System/\*physiology/\*Nervous System  
Physiology/Vestibule/\*physiology/\*Visual  
Perception

Scheer MS, Carlin DJ. Stroke after roller coaster-induced carotid compression. JAMA 1979 Oct 19;242(16):1769.

**SUBJECT HEADINGS:**

Accidents/Adolescence/Aphasia/etiology/Carotid  
Artery Thrombosis/\*etiology/Carotid Artery,  
Internal/injuries/Case Report/Cerebrovascular  
Disorders/\*etiology/Female/Human/Neck/injuries/  
Neck Injuries/\*Recreation

Schievink WL, Ebersold MJ, Atkinson JL.  
Roller-coaster headache due to spinal

cerebrospinal fluid leak [letter]. Lancet 1996  
May 18;347(9012):1409.

**SUBJECT HEADINGS:** Adult/Case  
Report/\*Cerebrospinal

Fluid/Female/Headache/\*etiology/Human/Hypotension, Orthostatic/\*etiology/\*Recreation

Senegor M. Traumatic pericallosal aneurysm in a patient with no major trauma. Case report. J Neurosurg 1991 Sep;75(3):475-7.

**ABSTRACT:** The case of a young woman who developed a traumatic distal anterior cerebral artery ("pericallosal") aneurysm from a roller-coaster ride is described. She presented with a subarachnoid hemorrhage (SAH) restricted to the interhemispheric fissure. The initial angiogram was normal but repeat angiography at 8 days revealed the aneurysm. After craniotomy and clipping the patient made a satisfactory recovery. This is the only reported case of a traumatic aneurysm arising under circumstances not usually considered as trauma. It raises questions about the pathophysiology of the formation of such aneurysms and suggests that traumatic pericallosal aneurysms should be considered in SAH of unknown etiology. This case provides further evidence that repeat angiography occasionally helps reveal an aneurysm when the initial study fails to do so.

**SUBJECT HEADINGS:** Adult/Case

Report/Cerebral Angiography/Corpus  
Callosum/Female/Human/Intracranial  
Aneurysm/complications/\*diagnosis/etiology/Leisure Activities/Subarachnoid  
Hemorrhage/\*etiology

Senturia YD, Binns HJ, Christoffel KK, Tanz RR. Exposure corrected risk estimates for childhood product related injuries. Accid Anal Prev 1993 Aug;25(4):473-7.

**ABSTRACT:** This study assesses the effect of exposure correction on injury risk estimates for children, using Chicago-area survey data on age-specific exposure of children to seven products: amusement park rides, sleds, bunkbeds, skateboards, fireworks, toboggans, and air guns and rifles. National Electronic Injury Surveillance System estimates for 1987 were used as numerators with two denominators: (i) uncorrected age-specific U.S. Census estimates for 1987 and (ii) these estimates corrected for exposure. Except for bunkbeds, skateboards and

sleds, corrected injury risk decreased as age increased. Uncorrected population injury rates underestimated the risk posed to product-using children, especially those who are youngest and those who use skateboards.

SUBJECT HEADINGS: Accidents/\*statistics & numerical data/Adolescence/Adult/Age Factors/Child/Child, Preschool/\*Consumer Product Safety/Female/Human/Infant/Male/\*Play and Playthings/Risk/United States/epidemiology/Wounds and Injuries/epidemiology

Senturia YD, Binns HJ, Christoffel KK, Tanz RR. In-office survey of children's hazard exposure in the Chicago area: age-specific exposure information and methodological lessons. *Pediatric Practice Research Group. J Dev Behav Pediatr* 1993 Jun;14(3):169-75.

ABSTRACT: Anticipatory guidance on injury prevention should reflect the risks children face, yet hazard exposure information is generally unavailable. The objectives of this study were (1) to obtain information on age-specific exposure of Chicago-area children to amusement park rides, sleds, snow discs, bunkbeds, skateboards, fireworks, toboggans, and air guns and (2) to assess methodological issues in gathering exposure information by parental survey in pediatric practices. Questionnaires were received from 679 families, including 1469 children. The proportion of families with at least one exposed child varied: amusement park rides (94%), sleds (67%), snow discs (25%), bunkbeds (24%), skateboards (22%), fireworks (17%), toboggans (15%), and air guns and rifles (6%). Use of skateboards, air guns and rifles, and bunkbeds was highest in males. Use of skateboards, air guns and rifles, and snow discs peaked among young adolescents (ages 10 to 14), whereas use of sleds, toboggans and amusement park rides peaked among young children (ages 5 to 9) and young adolescents. Use of bunkbeds peaked among young children. Log linear analyses found: the likelihood of exposure to sleds and snow discs was highest in rural communities and for families owning their own home; toboggan exposure was highest among home owners; air gun and rifle exposure was highest in rural areas; fireworks exposure decreased with increased paternal education; exposure to skateboards was highest in single family dwellings and suburban home owners. This study generates the only available current estimates for use of these

products, and demonstrates that in-office parental surveys concerning exposure are feasible. The findings can help guide future hazard exposure research and may affect anticipatory guidance in some settings.(ABSTRACT TRUNCATED AT 250 WORDS).

SUBJECT HEADINGS: Adult/Age Factors/Chicago/epidemiology/Child/Child Welfare/Child, Preschool/\*Data Collection/\*Environmental Exposure/Family/Female/Human/Male/Middle Age/Proportional Hazards Models/Risk Factors/Sex Factors/United States/epidemiology/Wounds and Injuries/epidemiology/\*prevention & control

Snyder RW, Sridharan ST, Pagnanelli DM. Subdural hematoma following roller coaster ride while anticoagulated. *Am J Med* 1997 May; 102(5):488-9.

SUBJECT HEADINGS: Aged/Anticoagulants/\*adverse effects/Case Report/Fatal Outcome/Hematoma, Subdural/chemically induced/\*etiology/Human/Male/\*Movement/Warfarin/\*adverse effects

von Baumgarten RJ, Baldrighi G, Vogel H, Thumler R. Physiological response to hyper- and hypogravity during rollercoaster flight. *Aviat Space Environ Med* 1980 Feb;51(2):145-54.

ABSTRACT: Healthy male subjects--26--were flown in a Lear jet aircraft through rollercoaster and parabolic weightlessness flight. Eye movements, respiration, and blood volume pulse were recorded on magnetic tape. The same subjects underwent a battery of five vestibular tests in the laboratory on the ground. One subject in each flight was flown in an upright position, the other in a 90 degree forward tilted head position. The forward tilted subjects always reported motion sickness earlier and after fewer rollercoaster manoeuvres than the upright sitting subjects. It is concluded that the susceptibility to changes of X-axis acceleration is higher than to changes of Z-axis acceleration. Correlation was found between the ability to estimate the subjective vertical (modified Muller-Aubert-test), optokinetic nystagmus asymmetries, and susceptibility to rollercoaster flight sickness.

SUBJECT HEADINGS: Adult/\* Aerospace  
Medicine/Blood Volume/Coriolis Force/Eye  
Movements/\* Gravitation/Human/Kinetics/Male/  
Motion Sickness/\* physiopathology/  
Posture/Respiration/Support, U.S. Gov't, Non-  
P.H.S.